Appendix L

Detailed Cost-Effectiveness Analysis of Vehicle Carrier Ships

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This appendix contains a more thorough discussion of the cost-effectiveness analyses conducted for vehicle carrier ships than what was provided in Chapter X. For brevity and clarity, Chapter X addressed NOx emissions reductions for vehicle carrier ships burning 0.1 percent sulfur distillate fuel, with the necessary electrical transformer located on the shore—the most likely scenario. Appendix L further addresses the reduction of other pollutants, the use of 0.5 percent sulfur distillate fuel, and the construction of the electrical transformers on the ships.

Vehicle carrier ships principally visit POLA/POLB, Hueneme, and San Diego, and to a lesser extent Carquinez, Richmond, and Oakland.

As was done previously for other ship categories, for each port, cost-effectiveness values were determined for three scenarios: 1) all ships visiting the port are cold-ironed; 2) only ships that make three or more visits per year to a port are cold-ironed; and 3) only ships that make six or more visits per year to a port are cold-ironed. In addition, the cost-effectiveness scenarios consider whether the necessary electrical transformers are constructed at the port (shore-side) or on the ships (ship-side).

Tables L-1 through L-5 show the “all pollutants” cost-effectiveness values calculated for the ports that vehicle carrier ships frequent.

Table L-1: All Pollutants Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at San Diego (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$120,000	$130,000
--shore-side transformer	$51,000	$58,000
Ships making 3 or more visits		
--ship-side transformer	$79,000	$89,000
--shore-side transformer	$51,000	$57,000
Ships making 6 or more visits		
--ship-side transformer	$83,000	$94,000
--shore-side transformer	$70,000	$80,000

Table L-2: All Pollutants Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Hueneme (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$120,000	$140,000
--shore-side transformer	$49,000	$56,000
Ships making 3 or more visits		
--ship-side transformer	$100,000	$110,000
--shore-side transformer	$56,000	$64,000
Ships making 6 or more visits		
--ship-side transformer	$190,000	$220,000
--shore-side transformer	$210,000	$240,000

Table L-3: All Pollutants Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at POLA/POLB (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$110,000	$120,000
--shore-side transformer	$60,000	$68,000
Ships making 3 or more visits		
--ship-side transformer	$85,000	$96,000
--shore-side transformer	$62,000	$70,000
Ships making 6 or more visits		
--ship-side transformer	$80,000	$91,000
--shore-side transformer	$96,000	$110,000

Table L-4: All Pollutants Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Carquinez (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$120,000	$130,000
--shore-side transformer	$56,000	$64,000
Ships making 3 or more visits		
--ship-side transformer	$190,000	$220,000
--shore-side transformer	$160,000	$180,000

Table L-5: All Pollutants Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Richmond (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$130,000	$150,000
--shore-side transformer	$67,000	$77,000
Ships making 3 or more visits		
--ship-side transformer	$110,000	$120,000
--shore-side transformer	$82,000	$93,000

The tables above show that the average cost-effectiveness values are high for this ship category. The scenarios where vehicle carriers visited six or more times had the highest average cost-effectiveness values because there were so few ships that met this criterion. (In fact, no ships visited Carquinez and Richmond at least six times.) Poor berth utilization (minimal ship traffic) results in poor cost-effective values.

Tables L-6 through L-10 show the NOx reduction cost-effectiveness values calculated for the vehicle carrier ships. As discussed in previous chapters, the use of distillate fuel has minimal impact on the NOx-only cost-effectiveness values, as distillate fuel has a modest NOx reduction benefit.

Table L-6: NOx Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at San Diego (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$140,000	$140,000
--shore-side transformer	$62,000	$62,000
Ships making 3 or more visits		
--ship-side transformer	$95,000	$95,000
--shore-side transformer	$61,000	$61,000
Ships making 6 or more visits		
--ship-side transformer	$100,000	$100,000
--shore-side transformer	$85,000	$85,000

Table L-7: NOx Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Hueneme (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$150,000	$150,000
--shore-side transformer	$60,000	$60,000
Ships making 3 or more visits		
--ship-side transformer	$120,000	$120,000
--shore-side transformer	$68,000	$68,000
Ships making 6 or more visits		
--ship-side transformer	$230,000	$230,000
--shore-side transformer	$250,000	$250,000

Table L-8: NOx Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at POLA/POLB (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$130,000	$130,000
--shore-side transformer	$72,000	$72,000
Ships making 3 or more visits		
--ship-side transformer	$100,000	$100,000
--shore-side transformer	$75,000	$75,000
Ships making 6 or more visits		
--ship-side transformer	$97,000	$97,000
--shore-side transformer	$120,000	$120,000

Table L-9: NOx Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Carquinez (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$140,000	$140,000
--shore-side transformer	$68,000	$68,000
Ships making 3 or more visits		
--ship-side transformer	$230,000	$230,000
--shore-side transformer	$190,000	$190,000

Table L-10: NOx Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Richmond (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$160,000	$160,000
--shore-side transformer	$81,000	$81,000
Ships making 3 or more visits		
--ship-side transformer	$130,000	$130,000
--shore-side transformer	$99,000	$99,000

Tables L-11 through L-15 show the PM reduction cost-effectiveness values calculated for the vehicle carrier ships. As with the other ship categories, the average cost-effectiveness values are quite high, but especially so for vehicle carriers.

Table L-11: PM Reductions Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at San Diego (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$5,300,000	$8,200,000
--shore-side transformer	$2,300,000	$3,600,000
Ships making 3 or more visits		
--ship-side transformer	$3,600,000	$5,500,000
--shore-side transformer	$2,300,000	$3,600,000
Ships making 6 or more visits		
--ship-side transformer	$3,800,000	$5,900,000
--shore-side transformer	$3,200,000	$5,000,000

Table L-12: PM Reductions Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Hueneme (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$5,500,000	$8,500,000
--shore-side transformer	$2,200,000	$3,500,000
Ships making 3 or more visits		
--ship-side transformer	$4,600,000	$7,100,000
--shore-side transformer	$2,600,000	$4,000,000
Ships making 6 or more visits		
--ship-side transformer	$8,700,000	$14,000,000
--shore-side transformer	$9,500,000	$15,000,000

Table L-13: PM Reductions Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at POLA/POLB (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$5,000,000	$7,700,000
--shore-side transformer	$2,700,000	$4,200,000
Ships making 3 or more visits		
--ship-side transformer	$3,800,000	$6,000,000
--shore-side transformer	$2,800,000	$4,400,000
Ships making 6 or more visits		
--ship-side transformer	$3,600,000	$5,600,000
--shore-side transformer	$4,400,000	$6,700,000

Table L-14: PM Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Carquinez (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$5,300,000	$8,200,000
--shore-side transformer	$2,500,000	$3,900,000
Ships making 3 or more visits		
--ship-side transformer	$8,600,000	$13,000,000
--shore-side transformer	$7,100,000	$11,000,000

Table L-15: PM Reduction Cost Effectiveness for Cold-Ironing Vehicle Carrier Ships at Richmond (Dollars/ton)

Description	Distillate Fuel (0.5% Sulfur)	Distillate Fuel (0.1% Sulfur)
All Ships		
--ship-side transformer	$6,000,000	$9,300,000
--shore-side transformer	$3,100,000	$4,700,000
Ships making 3 or more visits		
--ship-side transformer	$4,900,000	$7,600,000
--shore-side transformer	$3,700,000	$5,800,000

The prior analyses have all addressed *average* cost effectiveness. When cold-ironing all ships, these average values include many ships that visit a few times and a few ships that visit many times. The following analysis will address the cost effectiveness of cold-ironing an incremental ship if the shore-side infrastructure is already in place.

Tables L-16 provides incremental cost-effectiveness values for NOx reductions only, PM reductions only, and all pollutants for vehicle carriers, using 0.1 percent sulfur distillate fuel.

Table L-16: Incremental Cost Effectiveness to Retrofit a Vehicle Carrier Ship Using Distillate Fuel (0.1 percent sulfur) (Dollars/Ton)

Visits	NOx	PM	All Pollutants
1	$141,000	$8,300,000	$130,000
3	$52,000	$3,100,000	$49,000
5	$35,000	$2,000,000	$33,000
7	$27,000	$1,600,000	$25,000

Not surprisingly, the incremental cost-effectiveness values drop significantly with more visits made by a ship. These incremental cost-effectiveness values are somewhat misleading in that they assume the shore-side infrastructure has already been installed. The average cost-effectiveness values presented earlier may cast doubt on that premise.